TO WHOM IT MAY CONCERN

I, Andreas Roth, of Saebener Str. 9, 81547 Muenchen, Germany, do hereby solemnly declare that I am conversant with both the English and German languages and that the enclosed English text is, to the best of my knowledge and belief, a true and accurate English translation of the German-language text of German Patent Application No. 103 16 533.9, filed by Carl Zeiss on April 10, 2003.

Munich, this 5th day of April 2004.

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Attorney's File: PAT 3423/034

April 10, 2003

Hybrid HMD Device

The present invention relates to an HMD device (Head Mounted Display device).

In such devices, a wide field angle and a large exit pupil are generally desired. As a result, in known HMD devices, it is required to provide complex and large optics, making the weight of the HMD device disadvantageously high. Existing approaches using diffractive optics have the disadvantage that they only function in a monochromatic manner.

In view of the above, it is the object of the present invention to provide an HMD device which has a compact and low-weight design and simultaneously allows polychromatic operation thereof.

According to the invention, the object is achieved by an HMD device comprising an image-generating unit for generating a polychromatic image, deflection optics comprising first and second partial optics, said deflection optics projecting the image such that it is perceivable by a user wearing said HMD device, wherein each of said two partial optics contains a diffractive optical unit for beam deflection, which are designed such that their dispersion errors compensate each other.

By providing the two diffractive optical units, whose dispersion errors compensate each other, it is achieved, on the one hand, that the HMD device may be polychromatically operated. On the other hand, the use of the diffractive optical units leads to a very compact design of the HMD device, because very large angles of deflection are realizable with the diffractive optical units.

Since an HMD device is often designed glasses- or helmet-like and the image-generating unit is, thus, not arranged in front of the observer's eye, but laterally on the observer's head, the use of two diffractive optical units is particularly advantageous. Thus, using the first diffractive optical unit, the polychromatic image generated by the image-generating unit, which is radiated, in

many cases, in a forward direction parallel to the viewing direction, may be deflected toward the second diffractive optical unit, which is arranged directly in front of the observer's eye, and the radiation of the image is then deflected toward the observer's eye by the second diffractive optical unit. For this purpose, it is particularly advantageous if the first diffractive optical unit is provided as a transmissive optical unit and the second diffractive optical unit is designed to be reflective. Also, both diffractive optical units may, of course, be either reflective or transmissive, and it is further possible that the first diffractive optical unit may be reflective and the second diffractive optical unit may be transmissive.

The compensation of the dispersion errors of the diffractive optical units referred to herein means that dispersion-related imaging errors are eliminated as completely as possible upon deflection, but are at least smaller than in the case where only one diffractive optical unit is used.

In a preferred embodiment of the HMD device according to the invention, use is made of a non-zeroth order of diffraction of the diffractive optical units for beam deflection, wherein, in particular, the same order of diffraction is used in both diffractive optical units.

Using a desired non-zeroth order of diffraction, the HMD device is very flexibly adjustable to predetermined marginal conditions. The embodiment wherein the same order of diffraction is used for both diffractive optical units leads to very good results of compensation.

Further, in the HMD device according to the invention, the diffractive optical unit of the first and/or second partial optics may be provided as a line grating. Nowadays, such a line grating is easy to manufacture with the required precision. Thus, it may be formed, for example, by means of holographic methods or by means of microstructuring methods known from the manufacture of semiconductors.

In particular, the line grating may merely serve the purpose of beam deflection. In this case, the focussing (imaging) effect is realized by further refractive elements. The deflection optics may be optimized for the specific case of application in a particularly easy manner by separation of the deflecting effect, on the one hand, and the focussing effect, on the other hand.

Of course, it is also possible that the line grating may serve the purpose of beam deflection and, at the same time, as an imaging (focussing) element. This allows to realize extremely compact deflection optics, so that the overall design of the HMD device may be small and light.

It is particularly advantageous if, for the imaging effect of the diffractive optical unit, the grating constant of the latter is varied. This allows the desired imaging effect to be adjusted with extreme precision.

The line grating may be formed on or in a curved, in particular a spherically curved, material interface. Said material interface may be, for example, an interface of a refractive element of the deflection optics. This allows to realize deflection optics, which are compact and comprise few elements, thus allowing to save weight. Forming the grating in or on a spherically curved material interface has the advantage that spherically curved interfaces can be manufactured with extremely high precision. The desired or required aspherical effect may then be realized by means of the grating thus formed (in which case the grating thus serves the purpose of beam deflection and imaging). Thus, an easy-to-manufacture optical element having excellent imaging properties is provided.

It is further possible to form the line grating on or in a planar material interface. Of course, this further simplifies manufacture because planar surfaces are extremely well manageable during manufacture and planar surfaces allow a grating to be formed thereon with very high precision. In this embodiment, in order to provide the effect of curved material interfaces, if this is desired, the line grating may be formed accordingly. In particular, the grating constant (or groove width, respectively) is suitably varied, causing the thus formed optical element to act as though it comprised a curved material interface.

A particularly preferred embodiment of the HMD device according to the invention consists in that the second partial optics arranged in front of the eye of a user wearing the HMD device are provided so as to allow the user to perceive his environment through said optics. This enables an augmented representation in the HMD device according to the invention.

In particular, the diffractive optical unit of the second partial optics is provided such that the diffractive optical unit of the second partial optics is transmissive for the user in the zeroth order of diffraction. Thus, a very compact HMD device is provided which is suitable for augmented representations.

Further, the second partial optics may have a refractive effect for correction of visual deficiencies of the user. The device according to the invention will then already incorporate glasses for correction of visual deficiencies.

The image-generating unit may be a luminous display, for example a transmissive or reflective LCD, an LCoS display or an LED, or a non-luminous display. In particular, the image-generating

unit may comprise a spatial light modulator, such as, for example, a tilting mirror matrix or an LCD module, or an LCoS module which is correspondingly controlled, wherein a separate light source is also provided, if necessary.

In particular, the HMD device may be provided such that the observer can only perceive the generated polchromatic image or that he perceives the generated image as superimposed on the environment (augmented representation). The deflection optics preferably generate a virtual (especially also an enlarged) image for the user which he then perceives. The HMD device may generate images for one or both eyes, the images for both eyes being represented, in particular, to create a three-dimensional impression of the image.

Of course, the HMD device may comprise still further elements, in particular if they are required for operation. Thus, for example, a computer may be provided which contains the image data of the images to be represented and transmits said image data (e.g. via a wireless link) to the image-generating unit, or which directly controls the image-generating unit in a suitable manner.

The invention is explained in more detail below, essentially by way of example, with reference to the only drawing.

The Figure schematically shows the optical structure of an embodiment of the HMD device according to the invention. In this embodiment, the HMD device comprises an image-generating unit 1 for generating polychromatic images, said image-generating unit 1 being followed, in this order, by first partial optics 2 which are transmissive and by second partial optics 3 which are part reflective and part transmissive. Both partial optics 2 and 3 form a deflecting unit 4 and are each provided as hybrid optical units containing both refractive and diffractive elements.

As is evident from the schematic representation of the only Figure, the first partial optics 2 comprise a first lens 5 (which is indicated in order to represent one or more refractive optical elements) as well as a first line grating 6 formed on the curved material interface of the first lens 5 facing away from the image-generating unit 1. In a similar manner, the second partial optics comprise a second lens 7 (shown in order to represent one or more refractive elements), with a second line grating 8 being provided on the curved material interface facing the observer's eye. The individual grating grooves of both line gratings 6 and 8 extend perpendicular to the drawing plane and both line gratings each have a grating constant which does not change.

As is evident from the optical ray paths indicated by way of example, the image-generating unit 1 generates a polychromatic image which is projected at the desired virtual image width (here, for example, at infinity) into the observer's eye, wherein the entrance pupil of the eye is

designated by the reference numeral 9. For this purpose, the first line grating 6 is provided such that the first order of diffraction indicated generates the desired deflection in the direction toward the second partial optics 3. In this case, the line grating 6 is optimized such that the highest diffraction efficiency is concentrated in the first order of diffraction. As is known to the person skilled in the art, this may be determined by the profile shape. In particular, blazed profile shapes may be employed here. The second line grating 8 is similarly provided such that the first order of diffraction realizes the desired deflection toward the entrance pupil 9 of the observer's eye. Both line gratings 6 and 8 are further embodied such that the dispersion errors occurring during diffraction of polychromatic light just compensate each other, it being possible, of course, to effect an optimization to make said compensation as complete as possible. This has the advantageous effect that the virtually projected image is presented to the observer without any chromatic errors. Using the line gratings 6 and 8, a very large angle of deflection may be realized, so that the overall design of the deflection optics 4 is very compact.

The second partial optics 3 may be provided such, in particular, that the grating is transmissive for the observer in its zeroth order of diffraction, which enables an augmented representation. In this case, it is further particularly preferred if the lens 7 is also used for correction of a visual deficiency of the observer.

If the second line grating is not formed on the material interface of the second lens 7 facing the observer, but on the other material interface, the lens 7 may also be employed for correction of a visual deficiency in the HMD operation where only the image generated by the image-generating unit 1 is perceivable.

Both line gratings 6 and 8 are preferably provided such that their grooves have the same depth. This simplifies their manufacture. Of course, a varying groove depth is also possible. Further, the groove width of the line gratings 6 and 8 may be varied across the grating (in particular, perpendicular to the longitudinal direction of the grooves). Such a varying groove width leads to a focussing effect (imaging effect) of the grating which may be utilized to make the deflection optics 4 still more compact and lighter.

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Attorney's File: PAT 3423/034

April 10, 2003

Claims

1. An HMD device comprising an image-generating unit (1) for generating a polychromatic image and deflection optics (4) comprising first and second partial optics (2, 3), said deflection optics (4) projecting the image such that it is perceivable by a user wearing said HMD device, wherein the two partial optics (2, 3) each contain a diffractive optical unit (5, 8) for beam deflection, which are designed such that their dispersion errors compensate each other.

2. The HMD device as claimed in Claim 1, wherein use is made of a non-zeroth order of diffraction of the diffractive optical units (5, 8) for beam deflection, wherein, in particular, the same order of diffraction is used for both diffractive optical units (5, 8).

3. The HMD device as claimed in any one of the above Claims, wherein the diffractive optical unit (5, 8) of the first and/or second partial optics (2, 3) is/are provided as a line grating.

4. The HMD device as claimed in Claim 3, wherein the line grating only serves the purpose of beam deflection.

5. The HMD device as claimed in Claim 3, wherein the line grating serves the purpose of beam deflection and also as an imaging optical element.

6. The HMD device as claimed in Claim 5, wherein the grating constant of the line grating varies with respect to the imaging effect.

7. The HMD device as claimed in any one of Claims 3 to 6, wherein the line grating is formed on or in a curved, in particular a spherically curved, material interface.

8. The HMD device as claimed in any one of Claims 3 to 6, wherein the line grating is formed on or in a planar material interface.

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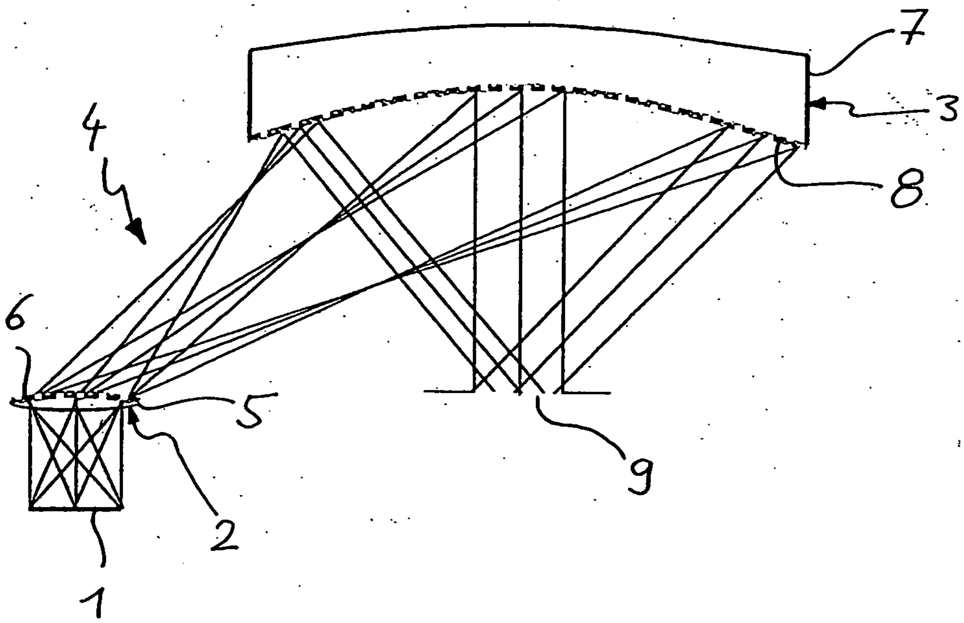
9. The HMD device as claimed in any one of the above Claims, wherein the second partial optics (3) arranged in front of the eye of a user wearing the HMD device are provided so as to allow the user to perceive his environment through said optics.

10. The HMD device as claimed in Claim 9, wherein the user can see through the diffractive optical unit (8) of the second partial optics (3) in the zeroth order of diffraction.

11. The HMD device as claimed in any one of the above Claims, wherein the second partial optics (3) have a refractive effect for correction of visual deficiencies of the user wearing the HMD device.



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April 10, 2003

Abstract

An HMD device comprising an image-generating unit (1) for generating a polychromatic image and deflection optics (4) comprising first and second partial optics (2, 3) is provided, said deflection optics (4) projecting the image such that it is perceivable by a user wearing said HMD device, wherein the two partial optics (2, 3) each contain a diffractive optical unit (5, 8) for beam deflection, which are designed such that their dispersion errors compensate each other.

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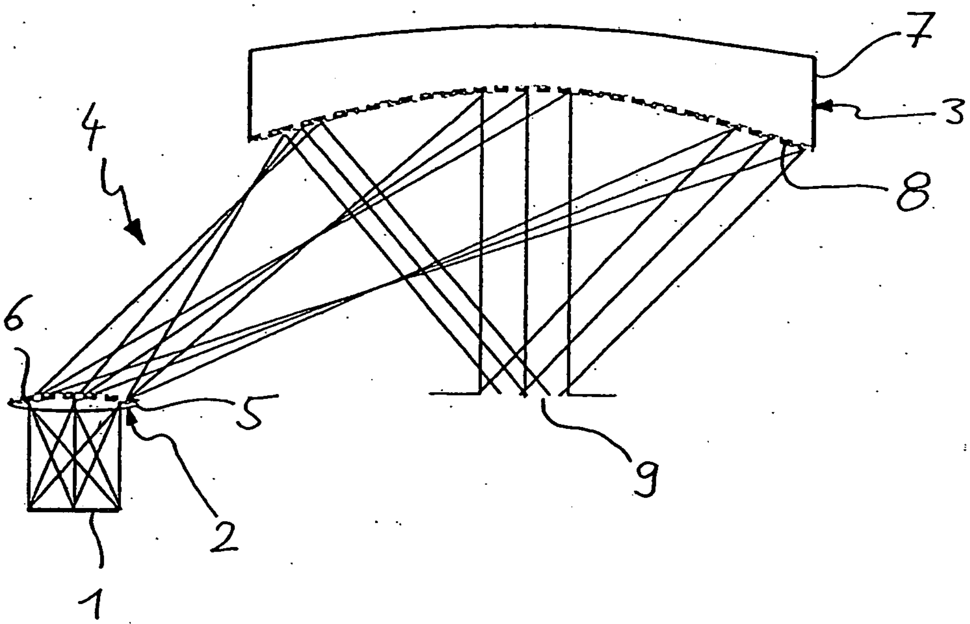

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